Radial Bearing Measurements of the 64-m Antenna, DSS 14

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This article describes the inspection fixtures and methods used to determine the extent of the azimuth radial bearing deformation at the 64-m DSS 14. An annular separation has developed between the circular steel runner and the grout, suggesting either failure of the grout or, as the case appears to be, stretching of the circular steel runner due to the formation of rust on the runner at the grout interface.

I. Introduction

At DSS 14 the azimuth radial bearing is a steel runner 9.144 m (30 ft) in diameter, mounted on the central concrete pedestal of the antenna and supported by grout between the steel runner and the rough concrete of the pedestal. Three truck assemblies, each with two large rollers which support the alidade base triangle at 120 degrees, are preloaded radially inward onto the steel runner and pedestal with a force of 1.47×10^6 newtons (330,000 lb) to eliminate motions of the antenna under maximum wind loads.

An annular separation has developed between the circular steel runner and the grout, suggesting either failure of the grout or, as the case appears to be, stretching of the circular steel runner due to the formation of rust on the runner at the grout interface.

II. Special Tooling

A set of inspection fixtures has been designed to study the changes in the radial bearing and to be used in case a major maintenance replacement of runner becomes necessary. A theodolite and a trammel bar assembly, located at the center of the antenna (Fig. 1), was used to establish a set of 24 equally spaced reference or bench marks located in a circle near the circular steel runner (Figs. 2 and 3). A second fixture (Fig. 4), which uses the bench marks for location, has been designed to measure the radial runout of the circular steel runner.

A review of tolerances and other operating considerations which affect the repeatability of measurements taken with the radial bearing inspection fixtures indicates the radial precision of the bench marks is ±0.127 mm (±0.005 in.) and that the repeatability of the measurements made with the base assembly and carriage, including the bench mark tolerance, is ±0.381 mm (±0.015 in.).

When used, the inspection fixture, which spans 30-deg, is moved in 15-deg increments around the antenna. Measurement points are indicated on top of the rail at 1/2-deg intervals. Several of the measurements made at each end of the fixture are repeated each time a set is made. This allows a check for repeatability of part of the data taken each time the inspection fixture is aligned with the bench marks.

A series of measurements was made over a 100-deg area (the antenna was at rest and 100 deg is about the maximum

that can be made between radial bearing trucks). The limited amount of time available prevented a complete 360-deg survey. Every precaution was made to assure the best possible repeatability during these measurements. A review of the data showed that the maximum difference between any of the repeated points was 0.203 mm (0.008 in.) and the mean of all of the repeated data was 0.076 mm (0.003 in.).

The inspection tools revealed that the circular steel runner had stretched more around the bottom edge than at the top, causing the radial bearing running surface to be conical instead of cylindrical. A verticality measurement tool was designed to measure the angular deviation from a vertical cylindrical surface (Fig. 5).

III. Observations

These data also indicated that there was a bulge midway between the radial bearing truck assemblies of approximately 0.9 to 1 mm (0.035 to 0.040 in.). Measurements made previously with the antenna parked at a different azimuth position indicated similar bulges but at a different azimuth location. To partially explain these bulges, consider a concrete ring 9.14 m (30 ft) OD, with a cross section 0.914 m (36 in.) thick and 2.03 m (80 in.) high (the dimensions of the portion of the pedestal which supports the radial bearing), with three inward radial loads of 1.47 to 1.78 newtons (330 to 400 kips) applied at 120-deg intervals. The outer surface at the point of application will distort inward.

The deflection inward may be estimated by the following formula:

$$\text{Deflection } \delta = \frac{WR^3}{2EI} \times \left[\frac{1}{(\sin \theta)} \right.$$

$$\left. \times \left(\frac{\theta}{2} - \frac{\sin \theta \cos \theta}{2} \right) - \frac{1}{\theta} \right]$$

where

$$\theta = \frac{120°}{2} = 60° = 1.047 \text{ radians}$$

$$R = 4.445 \text{ m } (175 \text{ in.}) \text{ (OD of concrete)}$$

$$I = \frac{2.032 (0.9144)^3}{12} = 0.12946 \text{ m}^4$$

$$E = 4.48 \times 10^{10} \text{ N/m}^2 \ (6.5 \times 10^6) \text{ (concrete)}$$

$$W = 1.779 \times 10^6 \text{ N/m}^2 \ (400,000 \text{ lb) (preload at present)}$$

$$\delta = \frac{1.7793 \times 10^6 \times (4.445)^3}{2 \times 4.48 \times 10^{10} \times 0.12946} \left[\frac{1}{(0.866)^2} \right.$$

$$\left. \times \left(\frac{1.047}{2} - \frac{0.866 \times 0.5}{2} \right) - \frac{1}{1.047} \right]$$

$$= 0.4257 \text{ mm } (0.017 \text{ in.}) \text{ inward deflection}$$

As the concrete ring is distorted inward, it will also be distorted outward midway between the truck assemblies. The approximation for this can be calculated by

$$\delta = \frac{WR^3}{4EI} \left[\frac{2}{\theta} - \frac{1}{\sin \theta} - \frac{\theta - \cos \theta}{(\sin \theta)^2} \right]$$

$$\delta = \frac{1.7793 \times 10^6 \times (4.445)^3}{4 \times 4.48 \times 10^{10} \times 0.12946}$$

$$\left[\frac{2}{1.047} - \frac{1}{0.866} - \frac{1.047 \times 0.5}{(0.866)^2} \right]$$

$$= 3.82 \times 10^{-4} \text{ m or } 0.381 \text{ mm } (0.015 \text{ in.})$$

The total deformation of the pedestal by the radial bearing preload is then approximately 0.4257 + 0.381 = 0.8067 mm (0.032 in.).

When the inspection tool was used, an amount approximately this great was observed between measurements made near the truck assemblies and the measurements made midway between the trucks.

The steel ring offers little opposition to the preload forces and will deflect inward or outward the same amount as the concrete. The ring complies in this manner because of the circumferential tension caused by the stretching of the ring due to rust. The radial force applied by stretching the steel runner can be estimated by the formula

$$P = \frac{\epsilon E \times 2t}{D}$$

For an average radial change in the runner at the center of approximately 0.050, the radial force is

$$\epsilon = \frac{2\pi \times 0.050}{2\pi \times 180} = 2.78 \times 10^4$$

and

$$P = \frac{2.78 \times 10^4 \times 20.677 \times 10^6 \times 2 \times 0.1016}{9.144}$$

$$= 1.28 \times 10^2 \text{ N}$$

which is negligible compared to the 1.78×10^6 newton preload.

The hoop stress is only $2.78 \times 10^{-4} \times 20 \times 10^{10} = 5.56 \times 10^7$ N/m^2 (8340 psi), well within the elastic limit of the steel.

IV. Conclusion

The result of these investigations indicates:

(1) The bench marks must be located with no preload on the radial bearing trucks, because the top of the pedestal will be distorted radially in the area of the bench marks when the preload is on.

(2) All measurements using the radial bearing inspection fixture must be made with the preload removed.

(3) The repeatability of the measurements made by the inspection tool with reasonable care should be adequate to relocate a replacement radial bearing runner if it becomes necessary.

(4) The repeatability of the inspection tool could be improved by locating it directly from the center theodolite mount using two equal rods to position it at each end, thereby eliminating several of the larger tolerance-contributing joints. This, however, would considerably increase the time needed to make a full set of observations.

(5) Should it be necessary to make measurements while the preload is on the radial bearing trucks, these measurements should be made radially between the theodolite mount in the center of the pedestal and a vertical bar, bearing on the center of the wearstrip, located between the wheels at one of the truck assemblies. Such a set of data would require rotation of the antenna in 15-deg increments and be good at the 15-deg points only.
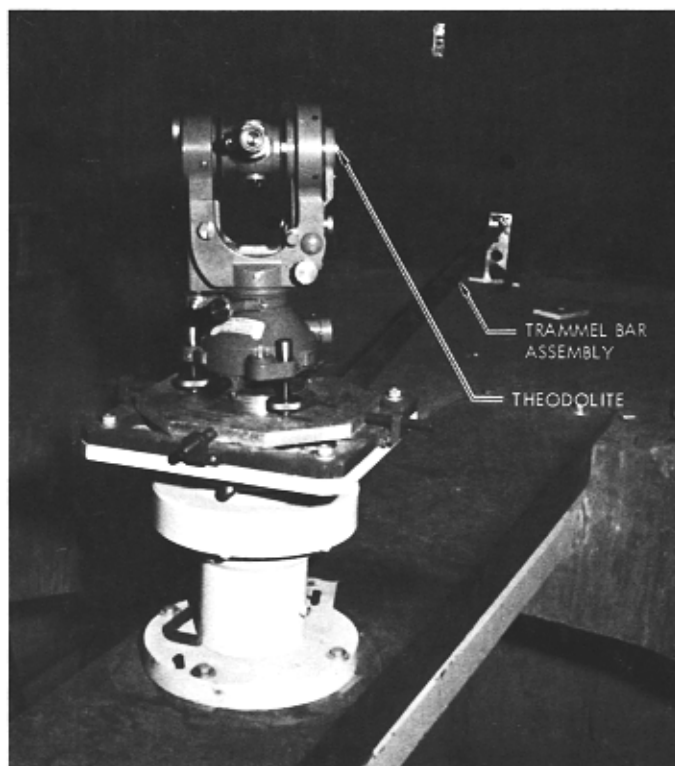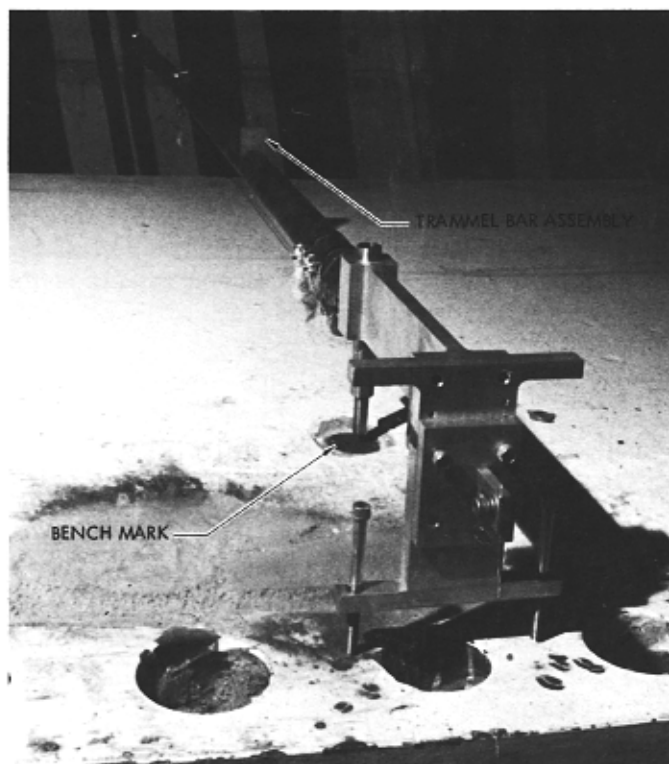
Fig. 1. Central theodolite and mount

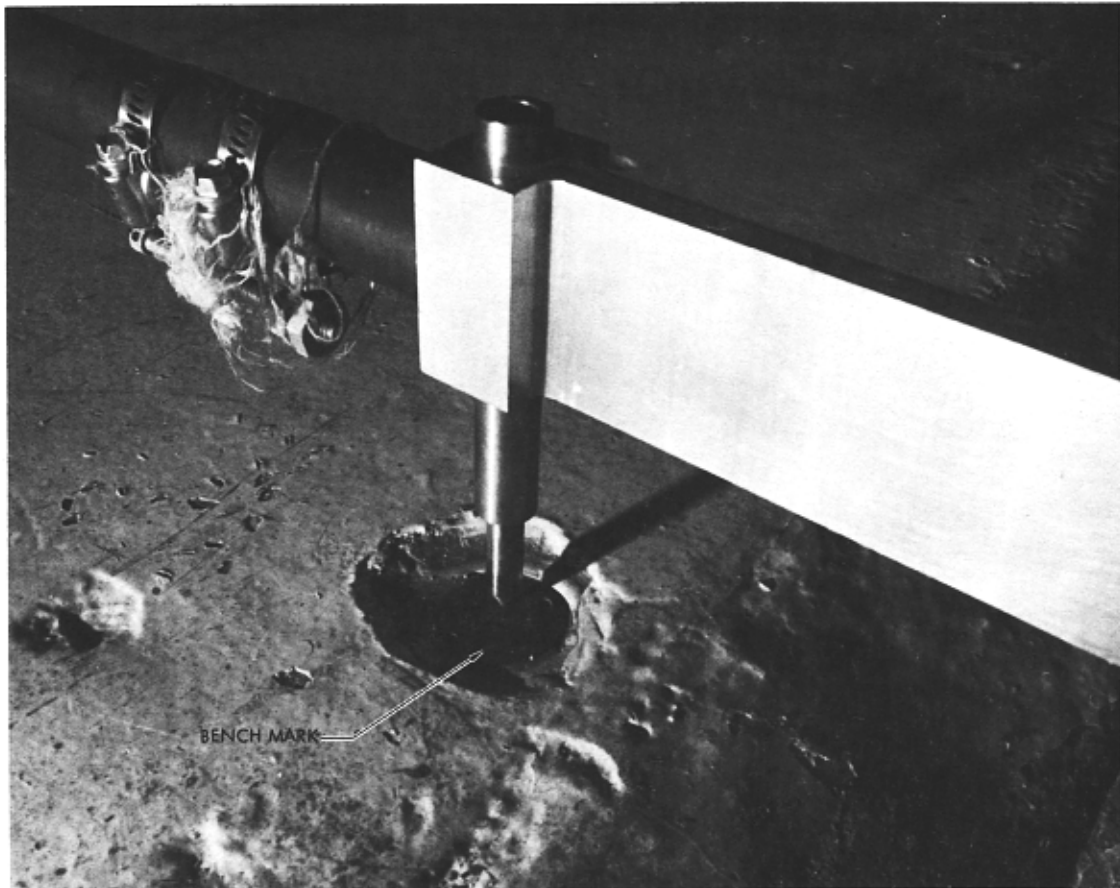Fig. 2. Bench mark and trammel bar assembly
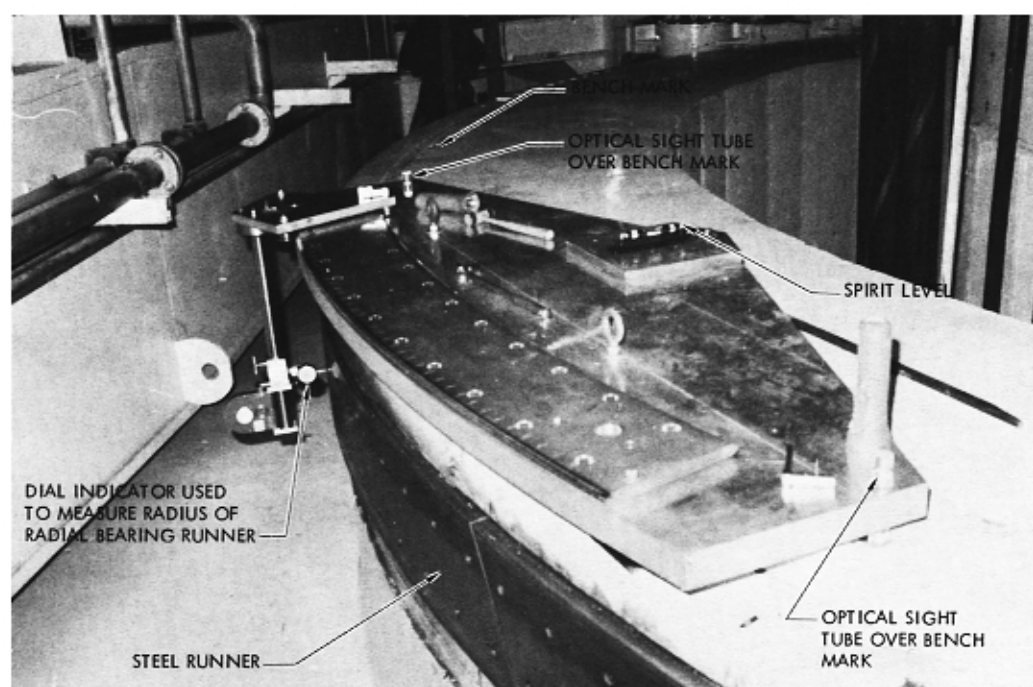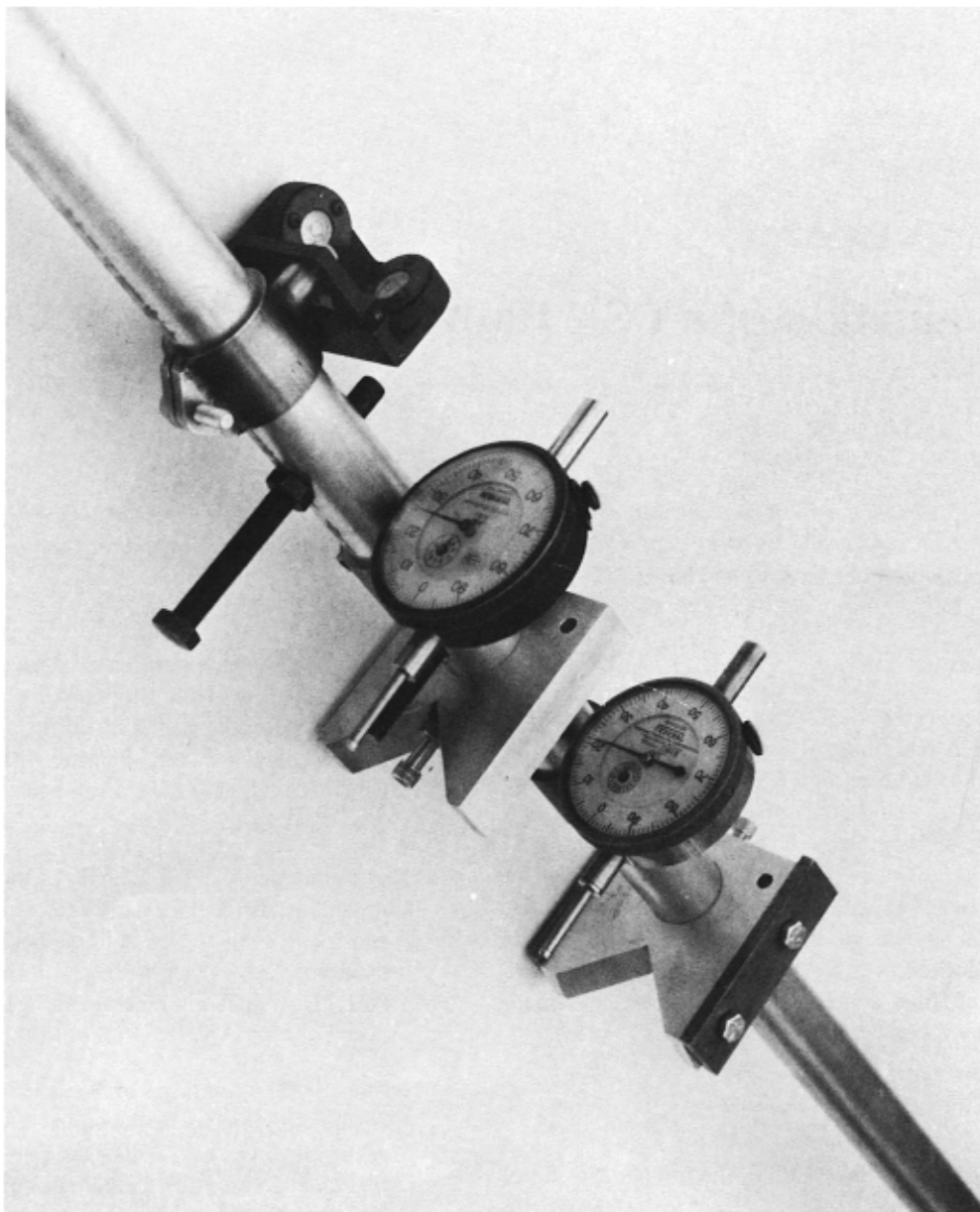
Fig. 3. Bench mark location

Fig. 4. Radial bearing measurement tool

Fig. 5. Verticality measurement tool